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ABSTRACT

This agriculture extension service publication from Pennsylvania State University is an introduction to weed control and herbicide use. An initial discussion of the characteristics of weeds includes scientific naming, weed competition with crops, weed dispersal and dormancy, and conditions affecting weed seed germination. The main body of the publication discusses herbicides. In this discussion topics included are: (1) growth-regulating herbicides; (2) contact herbicides; (3) chemical structure of herbicides; (4) herbicide formulations; (5) herbicide safety; (6) herbicide toxicity; and (7) factors affecting herbicide persistance. This publication could also be useful to people other than agricultural pesticide applicators. (MR)

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INTRODUCTION TO WEEDS AND HERBICIDES

Characteristics of weeds.....1
Herbicides.....5
Translocated (systemic) herbicides.5
Contact herbicides.....7
Time and method of application.....8
Structure.....8
Herbicide formulations.....11
Herbicide-liquid fertilizer combinations.....12
Herbicide safety.....13
Factors affecting herbicide persistence.....18

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A weed is a plant out of place, one which interferes with man's utilization of land. Weeds may occur as native or as introduced flora; 60 percent are introduced. Ten commonly accepted characteristics of weeds, in order of importance are:

Characteristic	Additional Comments
Indiscriminate, grows where not desired	Large; able to thrive anywhere
Competitive, aggressive	Reproduces many ways; establishes quickly; grows under poor conditions
Wild, rank	Large; grows quickly over wide area; is nitrogen-loving
Persistent, resistant,	Reproduces many ways; is protected from herbicides by form, biochemical tolerance, seed dormancy, or perennial nature.
Abundant	Adapts to crowding; has high seed numbers; is near mother plant
Useless and undesirable	Has no forage value, except perhaps as ground cover
Harmful to man, animals, crops	Has thorns or fibers; is poisonous, parasitic, or toxic
Spontaneous, not sown	Buried seed or parts are small and dormant; is sensitive and adaptable to tillage, crop cycles, and high fertility
Highly reproductive	Special structures aid dispersal; seeds are dormant
Unsightly	Is dominant, aggressive, unattractive in flowers or foliage; replaces desirable forms

NAMING WEEDS

All plants have a true, or scientific, name and a common name. The first word of the scientific name refers to genus; the second word to species. For example, Cyperus esculentus is the true name for yellow nutsedge.

Common names for any plant may differ from place to place. For example,

Agropyron repens is called quackgrass by the Weed Science Society of America, wiregrass in Pennsylvania, and couchgrass in Canada and England.

Discussing weeds is easiest if common names are used, but efforts to standardize common names are only pattially successful. Botanical names are awkward for general use, but are used in weed control literature to avoid confusion.

HOW WEEDS CAUSE LOSSES

Weeds cost Pennsylvanians at least $127 million each year: more than $100 million in field and forage crops; $15 million in horticultural crops; and more than $12 million in noncropland areas.

Weeds can host nematodes, or fungus and virus diseases; they can cause allergic reactions; they can taint food; and some can cause physical disorders or death. They also compete with crops, and interfere with planting, harvesting, and machinery efficiency. Some simply do not look good in a landscape.

SPREAD AND GROWTH OF WEEDS

DISPERSAL

Weed seeds are dispersed by natural forces and by animals or humans.

Natural forces include wind and water. Some weed seeds are small enough to be carried by water, and others, such as dandelion, are adapted to be moved by wind currents. In water, many seeds can float without damage.

Animals may carry seeds on barbs which attach to their hide or hair: beggarsticks and cocklebur are spread this way. Domestic animals may pass seeds through the digestive tract, infesting fields with weeds. If Johnsongrass appears near to feed lots, it will probably spread to fields. Birds spread weeds when intact seeds are passed through the digestive tract; mulberry and bitter nightshade are commonly spread by birds.

Man moves weed seed from one location to another in agricultural products, on machinery and clothing--in anything he handles. With equipment, he may drag tubers of nutsedge or rhizomes of quackgrass from one spot to another in fields.

DORMANCY

Seed dormancy is a survival mechanism for weeds. The three categories of seed dormancy are innate, induced, and enforced. The primary factors which affect dormancy are light, temperature, moisture, oxygen, afterripening, developmental stage of embryo, and condition and composition of seed coat.

INNATE DORMANCY

Innate dormancy means that after the seed leaves the parent plant, it requires some afterripening treatment, further development of immature embryos, leaching of natural inhibitors, or exposure to temperature extremes before germination can occur.

Seeds of different weed species vary in reaction to temperature. Crops are generally planted at or near optimum soil temperature for quick germination, but that may also be an ideal temperature for weed seeds.

Many seeds have a temporary dormancy which is broken by either low or high temperatures, preventing germination in the same season the seeds are produced and allowing the seeds to survive adverse weather conditions.

Water is required for germination. In dry soils, seeds may remain dormant until all other factors involved in promotion of germination reach at least a minimum level.

Seed coats may be waterproof, as are the coffeeweed seeds with their hard wax-like material over a dense covering around the embryo. Other hardseeds are morningglory, lespedeza, clover, and vetch.

Crop competition (shading) may intercept light rays and reduce weed seed germination when crops are in advanced stages of maturity.

The availability of oxygen is another factor which affects germination. Seeds may begin to germinate without air (anaerobic) and then shift to aerobic conditions when the seed coats rupture. Water may fill soil pores and exclude air, interfering with germination. Soil compaction may reduce the oxygen supply. Not cultivating at layby time keeps oxygen down, lowering the chances of germination.

INDUCED DORMANCY

Induced dormancy develops when a seed is exposed to specific environmental conditions, such as high soil temperatures, and becomes dormant. The dormancy lingers after conditions change. Yellow foxtail and smartweed react this way, and the seeds survive until the following spring when germination can occur.

ENFORCED DORMANCY

Enforced dormancy refers to environmental limitations which prevent germination. When the limitations are removed, seeds germinate freely. Plowing, deep tillage, or planting operations bring buried seed to the surface where they germinate readily. Special devices on turning plows bury weed seed at the bottom of the preceding furrow slice and enforce dormancy.

CONDITIONS AFFECTING WEED SEED GERMINATION

BURNING

Burning fields to destroy weed seed gives varying results, depending on heat intensity and duration. Many common weed seeds are destroyed when exposed to very high temperatures (175° to 212° F.) for 15 minutes. But if the burning creates only moderate heat, it may end dormancy of many seeds and induce increased germination because of greater temperature alternation, more light, less competition, and the removal of litter.

CUTTING

A common recommendation is to mow weeds to prevent seed production. The success of mowing depends upon proper timing.

Mowing when or before flower buds form prevents production of viable seed. But if flowers are open at mowing, much of the live seed falls back to the soil. Mowers often miss short-stemmed flowers which produce large numbers of seed.

STORAGE IN SILAGE

In storage, organic acids in silage kill many weed seeds within 10 to 20 days. However, some weed seeds may germinate after four years of silo storage.

SURVIVAL IN MANURE

Fresh manure spreads live weed seed, but well-rotted manure is generally free of living seed.

WEED REPRODUCTION

Weeds reproduce sexually or asexually. Sexual refers to those weeds that propagate by seed; asexual to those that reproduce by vegetative means such as runners, roots, or rhizomes.

HERBICIDES

Herbicides are chemicals used to kill plants or to interrupt normal plant growth. These chemicals can be classified in several ways: effect on plants; application time; application method; and similarity of chemical structure.

EFFECT ON PLANTS

Classification of herbicides by toxic effects is probably the most useful.

TRANSLOCATED HERBICIDES

Translocated (systemic) herbicides are absorbed by roots or leaves and distributed throughout the plant. The three groups of systemic herbicides are growth regulators, photosynthesis inhibitors, and cell-growth inhibitors.

GROWTH-REGULATING HERBICIDES

2,4-D	2,4-DEP (Falone)	MCPB
2,4,5-T	silvex	dicamba (Banvel D)
2,4-DB (Butoxone, Butyrac)	MCPA	picloram (Tordon)
		sesone

These herbicides cause responses similar to those of natural growth-regulating substances called auxins. Application of artificial auxins, such as 2,4-D, upsets normal growth as follows:

1. The cells of leaf veins rapidly divide and elongate, while cells between veins cease to divide. This results in a long, narrow, strap-like appearance of young leaves.

2. Water content increases, causing treated plants to be very brittle and easily broken.

3. Cell division and respiration rates increase; photosynthesis decreases. The food supply of treated plants is nearly exhausted at time of death.

4. Roots of treated plants lose their ability to take up soil nutrients, and stem tissues fail to move food effectively through the plant.

The killing action of the growth-regulating chemicals is not due to any single factor; plant death comes from the effect of several disturbances in the treated plant.

INJURY SYMPTOMS OF GROWTH-RFGULATING HERBICIDES

On broadleaf plants, the leaves are crinkled, puckered, strap-shaped, stunted, and malformed; the leaf veins appear parallel, rather than netted; and stems are crooked and brittle, with shortened internodes.

On grasses (corn, for example), growth-regulating herbicides cause leaves to roll near the base in an onion-like fashion; the tip of the terminal leaf is free; and stems are brittle, curved or crooked, and have short internodes.

HERBICIDES INHIBITING PHOTOSYNTHESIS

In the presence of light, green plants produce sugar from carbon dioxide and water. Energy is required to rearrange carbon, hydrogen, and oxygen atoms to form sugar. For this necessary energy, electrons are borrowed from chlorophyll (the green material in leaves), and replaced by electrons split from water. If chlorophyll electrons are not replaced, the chlorophyll is destroyed and the plant's food manufacturing system breaks down.

The triazine, substituted urea, and uracil herbicides all block chlorophyll electron replacement. As preemergence treatments, these herbicides permit normal seed germination and seedling emergence, but cause the seedlings to lose their green color soon after emergence. The seedlings die after the food supply in the seed is gone. At low rates, these herbicides are more effective on seedling weeds than on established weeds.

Inhibitors of Photosynthesis:

Triazines: atrazine, simazine (Princep), prometryne (Caparol), propazine (Milogard), prometone (Pramitol), cyanazine (Bladex), cyprazine (Outfox)

Uracils: terbacil (Sinbar), bromacil (Hyvar X)

Substituted ureas: diuron (Karmex), fluometuron (Cotoran), norea (Herban), linuron (Lorox), chloroxuron (Tenoran), fenuron (Dybar), monuron (Telvar)

INJURY SYMPTOMS OF PHOTOSYNTHESIS-INHIBITING HERBICIDES

On broadleaf plants, early seedling growth appears normal, but shortly after emergence, leaves become mottled, then turn yellow to brown and die.

Grasses germinate and grow normally to the two- or three-leaf stage; then the leaves turn light green to white and the seedling dies.

HERBICIDES INHIBITING CELL GROWTH

Herbicides in this group cause abnormal cell development or prevent cell division. The carbamate herbicides prevent cell division in roots and shoots

while permitting other cell duplication processes to continue. This causes death of bud tissues and eventually plant death.

The nitroanilines also prevent cell division. They act primarily on developing roots.

Dalapon prevents cell division, but apparently kills plants by preventing the production of a vitamin. Dalapon acts primarily on shoot tissue.

INJURY SYMPTOMS OF CELL-GROWTH-INHIBITING HERBICIDES

Carbamates: chlorpropham (Chloro IPC) vernolate (Vernam)
EPTC (Eptam) butylate (Sutan)

On broadleaf plants, the leaves turn dark green, become wrinkled, and fail to unfold from the bud; the roots are shortened, thickened, brittle and club-like.

Young leaves of grasses fail to unfold, resulting in a crooked-neck, onion-like appearance; the tip of the terminal leaf is rigid and not free-flapping (flag-like); the roots are shortened, thickened, brittle, and club-like.

Nitroanilines: trifluralin (Treflan) benefin (Balan)
profluralin (Tolban) dinitramine (Cobex)
penoxalin (Prowl) butralin (Amex 820)

Seeds of treated broadleaf plants germinate but fail to emerge or emerge as severely stunted seedlings; seedlings have a thickened, shortened lower stem, small leaves and short, club-shaped roots.

Grass seeds germinate but generally fail to emerge; injured seedlings have short, club-shaped roots, and thickened, brittle stem tissue.

Dalapon: Dowpon

On broadleaf plants, the leaves are brown, with a burned appearance; stems may be twisted; and flowers, if present, are deformed.

Grasses treated with dalapon have leaves which become straw-colored several days after treatment; young leaves may fail to unfold, resulting in an onion-like appearance.

CONTACT HERBICIDES

Contact herbicides are non-selective and are sometimes called caustic herbicides; they appear to burn plant tissues. The burn results from cellular breakdown by:

a. Direct injury to cell membranes: Phytotoxic herbicidal oils kill plants by dissolving parts of the cell wall.

b. Protein coagulation: Dinoseb (Dinitro) and PCP cause coagulation of proteins, and rapid plant death.

c. Inhibition of photosynthesis: Paraquat, diquat, linuron (Lorox) and prometryne (Caparol) oxidize chlorophyll and cause a buildup

of toxic materials which results in rapid death of treated tissues. The activity of these herbicides is delayed in the absence of light.

SOIL STERILANTS

Soil sterilants are a group of non-selective chemicals which keep the soil free of vegetation for one or more years. Many herbicides can be used as soil sterilants if applied at very high rates.

TIME AND METHOD OF APPLICATION

Herbicides can be broadly classified by time or method of application.

TIME

PREPLANT: Applied to the soil before crop planting. Example: butylate (Sutan) on corn.

PREEMERGENCE: Applied after crop is planted but before weeds emerge. Example: atrazine on corn.

POSTEMERGENCE: Applied after crop and weeds emerge. Example: dicamba (Banvel) on corn.

METHOD

BROADCAST: Applied over the entire field.
BAND: Applied to a narrow strip over crop drill row.
DIRECTED: Applied as a band directed toward the base of crop plant.
SPOT TREATMENT: Applied to small areas within a field.

STRUCTURE

Herbicides are often grouped together on the basis of similarity of chemical structure.

ORGANIC HERBICIDES

1. AROMATIC CARBOXYLIC ACIDS

Phenoxy herbicides:

2,4-D	
2,4,5-T	
2,4-DES	(Sesone)
2,4-DB	(Butyrac 200, Butoxone)
2,4-DEP	(Falone)
MCPA	(Methoxon)
MCPB	(Cantrol, Thistrol)

Benzoic acids:

dicamba	(Banvel D)
TIBA	
2,3,6-TBA	(Trysben, Benzac)
chloramben	(Amiben)

Phthalic acids:

naptalam	(Alanap)
DCPA	(Dacthal)

2. ALIPHATIC ACIDS

dalapon	(Dowpon)
TCA	(TCA)

Organic arsenical herbicides:

MSMA	(Ansar 170)
DSMA	(Ansar 184, Clout)
MAMA	(Ansar 157)
AMA	(Methar)
CMA	(Calar, Crab-E-Rad)
cacodylic acid	(Phytar, Erase)

3. HETEROCYCLIC NITROGEN DERIVATIVES

Ring substituted triazines:

ametryne	(Erik)
atrazine	
cyanazine	(Bladex)
cyprazine	(Outfox)
metribuzin	(Lexone, Sencor)
prometone	(Pramitol)
prometryne	(Caparol)
propazine	(Milogard)
simazine	(Princep)
procyazine	(Cycle)

Substituted uracils:

terbacil	(Sinbar)
bromacil	(Hyvar X)

Other heterocyclic nitrogen derivatives:

amitrole	(Amitrol)
picloram	(Tordon)
maleic hydrazide	(MH-30)

4. ALIPHATIC NITROGEN DERIVATIVES

Substituted ureas:

diuron	(Karmex)
norea	(Herban)
fluometuron	(Cotoran)
linuron	(Lorox)
chlorbromuron	(Maloran)
chloroxuron	(Tenoran)
fenuron	(Dybar)
manuron	(Telvar)

Substituted amides:

diphenamid	(Enide, Dymid)
CDAA	(Randox)
propachlor	(Ramrod)
alachlor	(Lasso)
propanil	(Stam)

Carbamates:

chloropropham	(Chloro IPC)
EPTC	(Eptam)
vernolate	(Vernam)
pebulate	(Tillam)
butylate	(Sutan)
prophram	(ICA Chem-Hoe)
barban	(Carbyne)
terbutol	(Azak)
CDEC	(Vegadex)
triallate	(Avadex BW)

5. NITROANILINES

trifluralin	(Treflan)
benefin	(Balan)
penoxalin	(Prowl)

6. SUBSTITUTED NITRILES

dichlobenil	(Casoron)
ioxynil	(Certol, Actril)
bromoxynil	(Brominal, Buctril)

7. SUBSTITUTED PHENOLS

dinoseb	(DNBP)
DNOC	(Sinox)
PCP	(Penta)

8. METAL ORGANIC HERBICIDES

sodium chlorate
calcium cyanamide (cyanamid)
sodium cyanate
potassium cyanate
phenyl mercuric acetate (PMA)
ammonium sulfamate (Ammate)

INORGANIC HERBICIDES

Sodium borate; arsenic trioxide; sodium arsenite; copper sulfate.

HERBICIDE FORMULATIONS

Herbicides are sold not as pure chemicals but as a combination or formulation of one or more herbicides with various additives. Surfactants, emulsifiers, adhesives, or various diluents may change the activity of a pure herbicide to the advantage of the user. Toxicity to plants, uniformity of plant coverage, and stability in storage depend on formulation. However, the primary function of formulation is to permit uniformity and ease of application. Herbicides are formulated to be applied as sprays, granules, or dusts.

SPRAYS

SOLUTIONS are homogeneous mixtures of two or more substances. A solution may be either clear or colored and cannot be separated by mechanical means. An example of a solution is 2,4-D amine dissolved in water.

EMULSIONS are one liquid dispersed in another, such as 2,4-D esters dispersed in water. Emulsions appear milky when dispersed in water. Without agitation, the liquids may separate.

WETTABLE POWDERS are finely divided solid particles that may be dispersed or suspended in water. Suspensions of wettable powders appear cloudy. Wettable powders are nearly insoluble and require agitation to remain in suspension. Atrazine and linuron are formulated as wettable powders.

GRANULES

Herbicides in granular formulations are applied in a dry state with a carrier. The carrier may be clay, sand, vermiculite, or ground corn cobs. Performance of granulated herbicides, compared with sprayable formulations, varies with the herbicide. Granular forms generally require more rainfall for activation than do sprayable formulations.

Advantages:

Water is not needed for application.
Relatively inexpensive equipment can be used for application.
May be very selective because granular particles fall off leaves, and sift through a canopy to the ground.

Disadvantages:

Heavy, bulky, troublesome to store or ship.
Small granules are subject to drift.
Application is not as uniform as sprays.

DUSTS

Dusts are popular formulations of insecticides and fungicides. Because of drift hazard, few herbicides are applied as dusts.

HERBICIDE-LIQUID FERTILIZER COMBINATIONS

Herbicides may be combined with liquid fertilizers to minimize trips over the field. Information is scarce concerning compatibility of herbicides with specific fertilizer solutions. Herbicide-fertilizer solution combinations may form a jell that will not flow through sprayer equipment. Other combinations may form solids that settle to the bottom of the sprayer tanks. The compatibility of herbicide-fertilizer combinations should be tested prior to mixing the components for field applications. In some cases, addition of a surfactant (Compex, Buffer X, or comparable surfactants) may aid in maintaining component dispersion.

The following procedure may be used to test the compatibility of herbicides with liquid fertilizers:

1. Fill two one-quart jars with the fertilizer solution to be tested. Add one teaspoon of surfactant to one of the jars.

2. Add the necessary amount of herbicide (as specified by the chart below).

Gallons of Liquid Fertilizer Per Acre*	Herbicide to be Added Per Quart of Fertilizer Solution**
10	5.0 teaspoons
15	3.0 "
20	2.5 "
25	2.0 "
30	1.5 "
50	1.0 "
100	0.5 "

* Test the components at the temperature that will exist in the field at application time. Incompatibility problems are most serious at low temperatures.

** The amounts listed are equivalent to approximately one quart of liquid herbicide or two pounds of wettable powder herbicide as the commercial formulation per acre.

Observation:

1. If, after standing for ten minutes, the components in the jar with no surfactant are dispersed, the herbicide is compatible and no surfactant is needed.

2. If the components are dispersed only in the jar containing surfactant, the herbicide is compatible only if a surfactant is added.

3. Should the components not be dispersed in either jar, then the herbicide-fertilizer solution mixture is not compatible and should not be used.

Should the herbicide-fertilizer mixture prove compatible in this test procedure, it may be applied as a mixture on a field basis, provided vigorous agitation is maintained in the spray tank.

HERBICIDE SAFETY

Recommended herbicides will not cause injury to humans, livestock, wildlife or crops if used properly and if recommended precautions are observed. However, any herbicide is potentially dangerous if improperly handled or used. Avoid splash or spray contact, and keep exposure to a minimum. Never keep herbicides in containers that are improperly labeled or easily accessible to children. Never dump unused herbicides where water supplies may be contaminated.

Most commonly available herbicides are given in the following table. They are listed in order of decreasing oral toxicity.

HIGHLY TOXIC HERBICIDES
(probable lethal dose for a 150-pound man is a few drops to 1 teaspoon)

Sodium arsenite [1,2]
Dinoseb (DNBP, Dinitro)[1]
Endothall (Aquathol, Des-i-cate)[3]

TOXIC HERBICIDES
(probable lethal dose for a 150-pound man is 1 teaspoon to 1 ounce)

Arsenic
PCP (Sod. Salt)[1]
Copper Sulfate (bluestone)
Diquat
Paraquat
DMPA (Zytron)[4]
2,4-D (acid)[4]
2,4,5-T (acid and ester)[4]

MODERATELY TOXIC HERBICIDES
(probable lethal dose for a 150-pound man is 1 ounce to 1 pint or 1 pound)

DSMA (Ansar 184, Clout)
MCPA (acid)
2,4-DB (Est'd)[3]
CDEC (Vegadex)[3]
Calcium Cyanamide (Cyanamid)
Diphenamid (Dymid, Enide)
MCPA (amine)
Linuron (Lorox)
EPTC (Eptam)
Vernolate (Vernam)
Arsenic acid
Norea (Herban)
DCPA (Dacthal)
Dicryl (Chloranocryl)
Monuron (Telvar)[4]
Chloroxuron (Tenoran)
Dalapon (Dowpon)[4]
Simazine (Princep)
Amitrol-T (Cytrol)
2,4-D (Sod. Salt)
2,4-D (Isop. ester)
AMA (Methar)
2,4-DES (Sesone)
Dicamba (Banvel-D)
Pebulate (Tillam)
Cacodylic acid (Phytar, Erase)
AMS (Ammate)
NPA (Alanap)
Bensulide (Betasan)
Dichlobenil (Casoron)
Prometryne (Caparol)
Atrazine
Diuron (Karmex)[4]
Chloramben (Amiben)
Prometryne (Caparol)
Propazine (Milogard)
Chlorpropham (CIPC)
Trifluralin (Treflan)

ALMOST NON-TOXIC HERBICIDES
(probable lethal dose for a 150-pound man is more than 1 pint)

Bromacil (Hyvar X)
MH (Sod. Salt)
Picloram (Tordon)
Benefin (Balan)
Amitrole (Weedazol)[4]
Sodium Borate[4]
Fenuron (Dybar)
Fluometron (Cotoran)
Sodium Chlorate[4]
Terbutol (Azak)

Dermal response: [1] is absorbed and poisonous
[2] causes burns and blisters
[3] is moderately irritating
[4] is mildly irritating

LIVESTOCK SAFETY

Herbicides sprayed on plants are not generally toxic to livestock, but animals may be poisoned by eating unused herbicides left in open containers or by drinking water contaminated with herbicides.

Certain unpalatable or poisonous plants treated with herbicides may become palatable to livestock. Be certain that livestock cannot get to poisonous plants which have been sprayed with herbicides.

The nitrate content of several kinds of weeds may be increased after spraying with 2,4-D, Banvel, or similar herbicides. Cattle browsing on these treated plants may become ill. Remove all animals from sprayed areas for several days or until after rain or after death of the weeds.

Milking dairy cattle should be kept off pastures for seven days after spraying with 2,4-D-type herbicides.

SAFETY TO GAME AND FISH

Controlled spraying may be beneficial to wildlife by maintaining desirable cover. Herbicides recommended for control of aquatic weeds give beneficial results for fish populations. Be sure to apply these herbicides properly Do not drain or flush equipment where chemicals may wash into ponds or streams, and do not leave open containers where curious animals might find them.

CROP SAFETY

Farmers are occasionally concerned about possible herbicide injury to crops. Most injury of this kind is caused by misuse, contaminated equipment, or drift. Unfavorable weather and herbicide residues from the previous crop are also often associated with herbicide effects on crops.

MISUSE

Improper sprayer calibration, non-uniform application, calculation errors, and use of the wrong chemicals can cause herbicide injury.

Only the recommended amount of herbicide should be applied. Slight increases in rate could result in crop injury or residues which would injure succeeding crops.

It is necessary to recalibrate sprayers frequently to adjust for increased output due to normal nozzle wear. Be sure there is sufficient agitation in the sprayer tank to prevent settling of wettable powders.

Do not stop sprayers in the field, spill tanks when loading, or dump unused herbicides where desirable plants are growing.

The following steps should be taken when mixing herbicides:

1. Calculate the amount of herbicide to add to the sprayer tank on the basis of the active material in each gallon of herbicidal concentrate or the percentage of active ingredient of wettable powder.

2. Read and follow the instructions on the manufacturer's label pertaining to personal hazards in handling.

3. Never pour concentrated herbicides into an empty tank.
   - *First fill the tank half-way with water.
   - *Operate sprayer by-pass to mix thoroughly and to maintain suspension by continuous agitation.
   - *Add the herbicidal concentrate.
   - *Finish filling the tank with water.

4. To ensure thorough mixing, operate the sprayer rig with the control value closed for several minutes. This by-passes the liquid into the tank.

5. Never allow a sprayer containing mixed chemicals to stand without agitation. Heavy wettable powders may clog nozzles or settle into corners of the spray tank.

6. Always be sure the sprayer has been calibrated properly to ensure the application of recommended rates.

CONTAMINATED EQUIPMENT

Sprayers used to apply 2,4-D-type herbicides may be used to apply other chemicals before crops are planted or before crop plants emerge, but equipment must be thoroughly cleaned before applications are made to emerged crops (except grasses). Ester formulations are harder to remove than are amine or salt formulations.

To remove esters, flush out the entire system with a water-detergent solution immediately after spraying. Then fill the tank and prime the system with an ammonia solution of one gallon of household ammonia to 100 gallons of water, and leave it undisturbed for 12 to 24 hours. Take the nozzles apart and soak the caps, screens, bodies, etc., in ammonia solution. (Five pounds of Sal soda or eight pounds of trisodium phosphate can be substituted for ammonia). Rinse the system thoroughly with water and let it circulate through the sprayer.

For falone or sesone formulations, follow the recommended procedure for esters, but use five gallons of vinegar instead of one gallon of ammonia.

After using amine or salt formulations or liquid herbicides, clean the equipment by flushing out the entire system with a water-detergent solution, and rinsing with clean water.

Wettable powder residues must be removed immediately after use: Flush the entire system with clean water, then remove sprayer nozzles and clean residues from screens. Rinse the system with a detergent solution followed by clean water. Replace the nozzles. (The herbicide label may suggest special cleaning procedures.)

As a test for a residual herbicide, spray a few plants of a susceptible crop four to five days before using the sprayer on large areas.

DRIFT

The term "drift" is applied to movement of any pesticide through the air to areas not intended for treatment.

Particle drift: At the time of application, small spray droplets or dust particles are carried by air movement from the application area to other areas.

Vapor drift: After application, herbicides evaporate (volatilize) and yield fumes (gases) which are carried on wind currents and deposited on soils or plants in untreated areas.

Drift may injure sensitive crops, ornamentals, gardens, livestock, wildlife, or people, and may contaminate streams, lakes, or buildings. It may contaminate crops and cause illegal or intolerable residues. Excessive drift may mean poor performance in the desired spray area because the application rate is less than expected.

Highly active chemicals present the greatest drift hazard, since extremely small amounts of these chemicals can cause severe problems. For example, growth-regulating herbicides, such as 2,4-D, dicamba, and picloram, at a rate of one ounce per acre, can deform sensitive crops, such as tobacco or tomatoes.

Vapor drift problems can often be avoided by use of non-volatile formulations. Essentially, no vapor drift hazard is involved in the use of amine formulations of 2,4-D.

Particle drift depends on the size of the particle or droplet; and droplet size depends on pressure and nozzle design. Very small particles of fog or mist size present the greatest drift hazard. To minimize particle drift, equipment should be calibrated to create droplets about the size of light rain.

Most nozzles can be adjusted to a pressure which permits droplet formation as a result of surface tension. If nozzles are operated for this pressure, a minimum of mist-sized droplets will be formed. For some nozzles, this pressure may be as little as 10 pounds per square inch; for others, 30 pounds per square inch.

The distance that particles will drift increases with the height of release. Wind velocities are usually lower close to the ground. Therefore, sprays should be released as near the soil surface or vegetation as adequate coverage will permit.

Drift hazard is usually minimized if prevailing winds are blowing away from sensitive crops. However, a sudden shift in wind direction could result in serious damage. If possible, do not apply pesticides when the wind is strong.

High temperatures increase the loss of volatile herbicides. Esters of 2,4-D rapidly evaporate at temperatures above 80° F. The use of such ester formulations should be restricted to fall, winter, and early spring because sensitive plants are not present, and because low temperatures reduce vapor drift hazard.

Drift control should be considered in every pesticide application. Severe problems associated with drift can be avoided by:

1. Using low volatile or non-volatile formulations
2. Using low spray delivery pressures (20-40 pounds per square inch)
3. Applying at high volume
4. Avoiding application of volatile chemicals at high temperatures
5. Spraying when wind speed is low and blowing away from areas that should not be contaminated
6. Leaving border areas unsprayed if they are near sensitive crops

EVALUATIONS OF POSSIBLE HERBICIDE INJURY

Insects, diseases, severe weather (hail, drought, flooding), fertilizer burn, nutrient deficiencies, and many other factors produce symptoms that can be easily confused with herbicide injury. In evaluating crop injury, it is necessary to consider:

1. Are similar symptoms present in treated and untreated areas within the same field or in crops grown in or near the area in question?
2. What is the history of the problem field--the fertility program, cropping sequence, land preparation, and seed source?

Careful consideration of these points will aid in the diagnosis of the problem.

FACTORS AFFECTING HERBICIDE PERSISTENCE

The residual life or length of time that a herbicide persists in the soil is the length of time that weed control can be expected. Residual toxicity, if not taken into consideration when planting in an herbicide-treated field, may injure succeeding crops.

The inactivation, breakdown, and disappearance of herbicides is influenced by soil and environmental factors.

MICROBIAL BREAKDOWN

Microorganisms use all types of organic matter, including organic herbicides, as food supplies. Some herbicides are more readily attacked by microorganisms than others. This is often due to minor differences in chemical structure which permit rapid decomposition in one case and block decomposition in others. Soil temperature, aeration, pH levels, organic matter, and moisture levels favorable for microbial growth promote rapid herbicide breakdown.

LEACHING

Water carries herbicides out of the root zone. The amount lost to leaching depends on soil texture, herbicide solubility, and amount and intensity of rainfall. As a rule, herbicides leach most from sandy soils and least

from clay soils and soils containing a high percentage of organic matter.

ADSORPTION

After application, herbicides may become adsorbed (bound) to clay and organic matter particles. The extent of adsorption increases as the percentage of organic matter and/or clay increases. Adsorption reduces the amount of chemical available to plants, slows leaching,and retards microbial breakdown.

CHEMICAL BREAKDOWN

Herbicides may be activated by reaction with water, salts, acids, and other substances in the soil. These reactions are affected by the same environmental factors that affect microbial breakdown.

VOLATILIZATION

Some herbicides may be rapidly lost as fumes after application. Loss as vapor reduces the persistence of nitroaniline and carbamate herbicides and of dichlobenil. The rate of vapor loss is influenced by soil moisture, temperature, and adsorption.

The loss of herbicides in vapor increases as sand, soil moisture, and soil temperature increases. Incorporation immediately after application prevents this kind of loss.

PHOTODECOMPOSITION

Sunlight may inactivate herbicides. This may be an important factor contributing to activity loss of unincorporated trifluralin (Treflan), nitralin (Planavin), and benefin (Balan). Light exposure of two or more hours reduces the effectiveness of trifluralin and related herbicides, and can be avoided by soil incorporation.

PLANT UPTAKE

Herbicides may be absorbed by plant roots or leaves and be either accumulated or inactivated within the plant. Generally, herbicide removal by plants accounts for a relatively small amount of herbicide loss.

PESTICIDE SAFETY

1. Observe all restrictions and precautions on pesticide labels.
2. Store all pesticides behind locked doors, in original containers with labels intact.
3. Use pesticides at correct dosages and intervals to avoid excessive residues and injury to plant and animals.
4. Apply pesticides carefully to avoid drifts.
5. Bury surplus pesticides and destroy used containers so that contamination and other hazards will not result. (See USDA Bulletin, "Safe Disposal of Empty Pesticide Containers and Surplus Pesticides," 1964).

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